

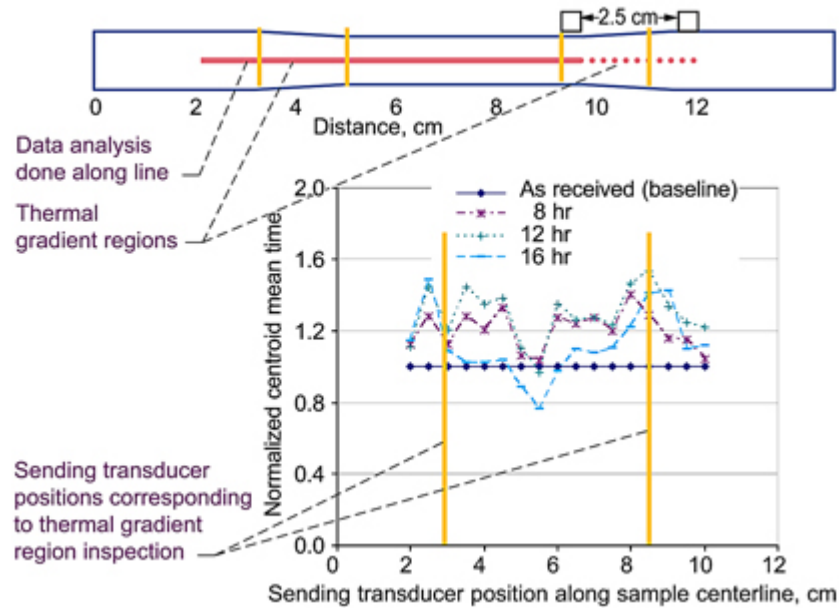
Ultrasonic Guided-Wave-Scan System Used to Characterize C-Enhanced Silicon Carbide Composite During Creep- Rupture Tests

Ceramic matrix composites (CMCs) are being developed for advanced aerospace propulsion applications in order to save weight, improve reuse capability, and increase performance. However, mechanical and environmental loads applied to CMCs can cause degradation in the form of discrete flaws and distributed microdamage that can play a significant role in reducing desirable physical properties. Categories of microdamage include fiber/matrix debonding (interface failure), matrix microcracking, fiber fracture and buckling, oxidation, and second-phase formation. Distributed microdamage in CMCs has proven difficult to characterize nondestructively because of the complex microstructure and macrostructure of these materials, and a recent study regarding the durability of a ceramic matrix composite discussed the requirement for improved nondestructive evaluation (NDE) methods for monitoring degradation in these materials.

This year, an ultrasonic guided-wave-scan system developed at the NASA Glenn Research Center was used to nondestructively characterize damage in C/SiC (carbon fiber in silicon carbide matrix) ceramic matrix composite samples that underwent high-temperature creep-rupture testing. The samples were creep tested to failure at 1200 °C in air at a stress of 69 MPa (10 ksi). The creep tests were interrupted for ultrasonic guided-wave evaluation every 2 hr until the material samples failed. The damage was expected to be primarily of the oxidation type, which results in the carbon fibers literally disappearing. Since ultrasonic testing has proven sensitive to characterizing voids in ceramics, the use of the ultrasonic guided-wave-scan system was explored for (1) mapping evolving oxidation profiles along the sample length (as manifested by evolving voids) and (2) predicting ultimate failure location.

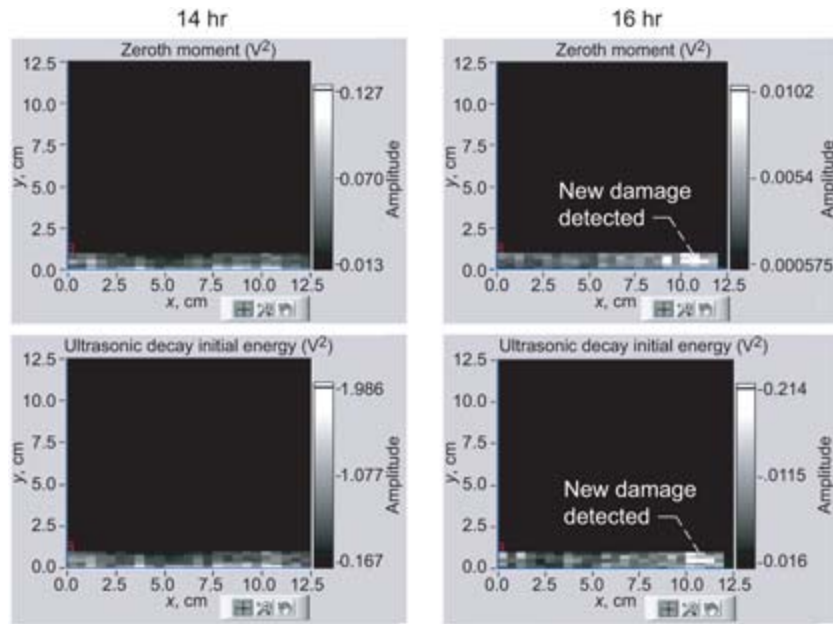
The ultrasonic guided-wave method used at Glenn results in complicated, multimode signals. These signals undergo specialized signal processing routines to extract parameters of the time and frequency domain. These parameters have proven to be sensitive to changes in microstructural conditions and to the presence of defects. In this study, one of the calculated parameters, centroid mean time, appeared to exhibit an evolving spatial trend that would be consistent with the nonuniform oxidation damage across the sample that has been reported previously. Specifically, normalized centroid mean time line profiles from 8 to 16 hr showed approximately 20- to 40-percent lower values at the center versus the thermal gradient regions in a creep-rupture-tested sample, possibly indicating a difference in porosity between these areas. In addition, initial energy images showed that two other calculated parameters, zeroth moment and ultrasonic decay, were clearly indicated at the eventual failure location for the sample 1.5 hr prior to

failure. This is a highly significant result since other nondestructive evaluation methods did not reveal these indications.



Normalized centroid mean time as a function of creep hours and locations along the centerline of the sample.

The preceding graph shows the normalized centroid mean time as a function of creep hours and locations along the centerline of the sample. This parameter, computed from the raw time domain ultrasonic signal, appears to resolve differences between oxidation behavior at the center versus the thermal gradient regions of the sample. The following figure shows the zeroth moment and ultrasonic decay initial energy images for the C/SiC sample after 14 hr and after 16 hr of creep tensile testing. Note the white indication in both 16-hr images at $x = 10$ to 11 cm. This was the eventual failure location, and it was not apparent after only 14 hr of testing.



Zeroth moment and ultrasonic decay initial energy images for C/SiC sample after 14 hr and after 16 hr of creep tensile testing.

Bibliography

Roth, Don, et al.: Characterization of C/Enhanced SiC Composite During Creep-Rupture Tests Using an Ultrasonic Guided Wave Scan System. NASA/TM--2004-213055, 2004. <http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2004/TM-2004-213055.html>

Glenn contact: Dr. Don Roth, 216-433-6017, Donald.J.Roth@nasa.gov

Authors: Dr. Don J. Roth, Laura M. Cosgriff, Richard E. Martin, and Michael J. Verrilli

Headquarters program office: OAT

Programs/Projects: UEET, RTF